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DESIGN OF CELLULAR COMPOSITES WITH METAMATERIAL MICROSTRUCTURES BY TOPOLOGY OPTIMIZATION OF LEVEL SETS

Zhen Luo[(1)], Tao Wu[(2)]

[(1)]University of Technology, Sydney, Australia
zhen.luo@uts.edu.au

[(2)]Huazhong Univesity of Science and Technology, China
wutao1972@hust.edu.cn

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Abstract: This paper is about topology optimization for an integrated multiscale design of cellular composites that consists of multiple regions of elastic metamaterial microstructures. The multiscale design mainly involves two optimization stages: the free material distribution optimization and the concurrent topological shape optimization. The macro structure is overall configured with multi-regional patches of different types of microstructures, while each patch is featured with identical material microstructures. At macro scale, a free material distribution method with a regularization mechanism is used to find a reference layout for global material distribution of different element densities. At micro scale, each macro element is treated as an individual microstructure corresponding to a discrete density. Hence, all the macro elements located within the same region can be represented only by one representative microstructure, due to the same discrete densities or volume fractions. Any of the representative microstructures can then be topologically optimized by a powerful level set method associated with the numerical homogenization method. The multiscale design is concurrently positioned into a unified process of design optimization, so both topology of the macrostructure, and the topologies and locations of the representative microstructures in the design space are optimized. Numerical examples show that the proposed method is able to improve the concerned structural performance under an affordable computation and manufacturing cost.